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DOI: https://doi.org/10.1007/s12593-014-0164-0

J Hand Microsurg (January–June 2015) 7(1):42–48
DOI 10.1007/s12593-014-0164-0

ORIGINAL ARTICLE

# Radiographs Versus Radiographic Measurements in Distal Radius Fractures

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Received: 2 July 2014 / Accepted: 13 October 2014 / Published online: 21 October 2014


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**Keywords** Distal radius fracture · Interobserver agreement · Patient characteristics · Radiographic measurements · Radiographs · Surgeon characteristics

## Introduction

Distal radius fractures are common and increasingly receive operative treatment. The indications for surgery depend on patient factors (e.g. age, health status, and activity level), fracture pattern and alignment, and associated injuries [1]. Surgeons use radiographic measures of deformity such as dorsal or volar tilt, intra-articular gap and step-off, ulnar variance, ulnarward inclination, and the presence of dorsal or palmar comminution, associated ulnar fracture, and severe osteoporosis to help making decisions [1]. To a limited and inconsistent degree, these pre- and post-operative radiographic measurements correlate with symptoms and disability after recovery [2].

We are trying to understand the substantial interobserver variability in treatment recommendations for fractures of the upper extremity [3–5]. It is possible that some of the variation arises during the measurement or estimation of radiographic deformity. We know that some surgeons estimate radiographic alignment rather than making quantitative measurements of the deformity in daily practice. In addition, radiographic measurements have limited reliability [6]. Furthermore, the radiographic appearance might have an influence beyond the measurements or numbers alone.

This study tested the primary null hypothesis that there is no difference in the interobserver variability of the surgeon's recommendation for operative treatment of a distal radius fracture on average when provided with a clinical scenario and either actual radiographs or just radiographic measurements without actually seeing the radiographs. The secondary

study questions addressed 1) surgeon factors and 2) patient factors associated with greater likelihood of recommending operative treatment.

## Material and Methods

Members of the Science of Variation group received an email-invitation in August 2013 to participate in this study. The Science of Variation Group is a collaborative group of orthopaedic surgeons from different geographic areas (Asia, Australia, Europe, North and South America) with the aim of understanding and diminishing interobserver variation; it is a web-based tool; participation is voluntary and recognized by a group authorship of resulting papers; and the surgeons are not involved in the treatment of presented case scenarios [7].

Participating surgeons read the case scenarios of 30 consecutive adult patients that presented to the emergency room of one Level 1 trauma center in February 2012 with a fracture of the distal radius. Clinical information provided to observers included age, sex, side, comorbidities, diagnosed osteoporosis, relevant medications (e.g. acetylsalicylic acid, clopidrogel, warfarin, and chemotherapeutic agents), and known alcohol or drug abuse. Observers were randomly distributed to receive either de-identified pre-reduction posteroanterior (PA) and lateral radiographs of the affected wrist (Fig. 1a), or radiographic measurements and descriptions only (AO Type, ulnar fracture, ulnar variance in millimeters, volar tilt, and radial angle in degrees, intraarticular gap and step in millimeters, and the presence of dorsal comminution, defined as more than 3 dorsal fragments on radiographs) without radiographs along with the clinical information (Fig. 1b). The radiographic measurements were made by an experienced trauma surgeon not involved in patient's care from the same radiographs shown to the other group of surgeons. We used the random number generator in excel for randomization.

Thirty eight percent of all invited surgeons (259/677) read and assessed all 30 case scenarios: 135 received radiographs and 124 received measurements. (Table 1) This should not be considered a survey response rate as many members do not treat distal radius fractures and some are on our list even though they rarely participate in studies. These groups were comparable with respect to sex, area of practice, years of practice, supervision of surgical trainees, and specialty. The surgeons were asked a single question: "Do you recommend operative treatment?" There was no time limit to complete the 30 case scenarios.

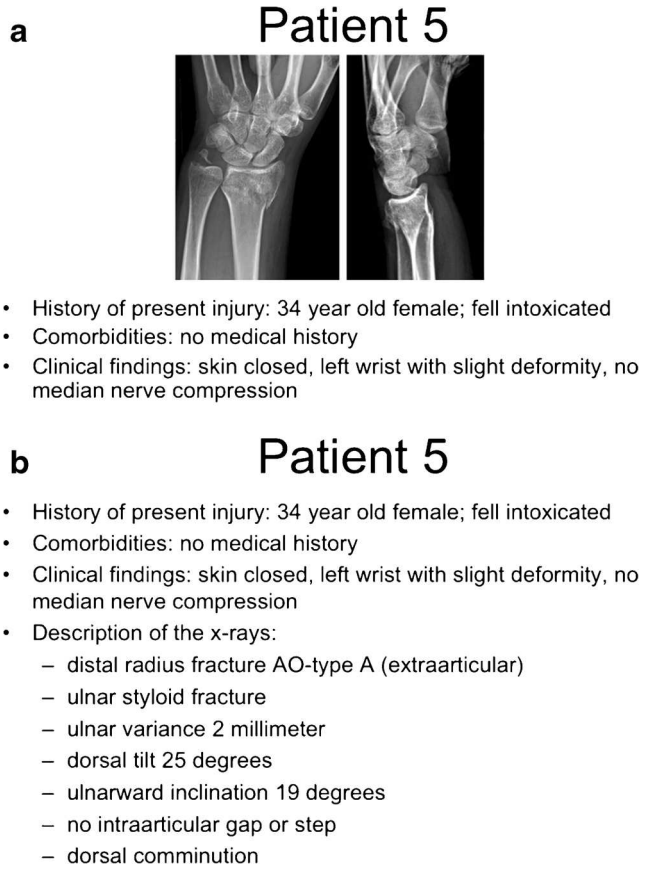


**Fig. 1** Observers were randomly distributed to receive either radiographs of the affected wrist (**a**), or radiographic measurements and descriptions only without radiographs along with the clinical information (**b**)

### Statistical Analysis

The multirater agreement on treatment choice (binary, operative vs. non-operative) was calculated with the Fleiss' generalized Kappa [5,8–10], which is a statistical chance-corrected measure for assessing multirater agreement with binary ratings. (Table 2) The calculated measures are presented as a value between 0 and 1 and are called Kappa value. They were interpreted according to the guidelines by Landis and Koch [11]: 0.01 through 0.20 represent slight agreement, 0.21 to 0.40 fair agreement, 0.41 to 0.60 moderate agreement, 0.61 to 0.80 substantial agreement, and above 0.81 is considered almost perfect agreement. Two-sample independent Z-tests were performed for each variable to compare the kappa for "Radiographs and clinical information" with that of "Radiographic measurements only with clinical information".

For all available surgeon and patient factors the average operative treatment recommendation rates were compared in bivariate analysis using chi-square tests and all significant or nearly significant parameters ($p<0.1$) were next entered into a backward logistic regression model to

**Table 1** Surgeons' characteristics

| Characteristics | Total $n$=259 | | Measurements and clinical information $n$=124 | | Radiographs and clinical information $n$=135 | | p-value |
|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | |
| Sex | | | | | | | |
| Male | 240 | 93 % | 116 | 94 % | 124 | 92 % | 0.60 |
| Female | 19 | 7.3 % | 8 | 6.5 % | 11 | 8.1 % | |
| Area of practice | | | | | | | |
| Asia | 8 | 3.1 % | 3 | 2.4 % | 5 | 3.7 % | 0.36 |
| Australia | 7 | 2.7 % | 3 | 2.4 % | 4 | 3.0 % | |
| Canada | 9 | 3.5 % | 3 | 2.4 % | 6 | 4.4 % | |
| Europe | 72 | 28 % | 37 | 30 % | 35 | 26 % | |
| United Kingdom | 5 | 1.9 % | 0 | | 5 | 3.7 % | |
| United States | 133 | 51 % | 67 | 54 % | 66 | 49 % | |
| Other | 25 | 9.7 % | 11 | 8.9 % | 14 | 10 % | |
| Years of practice | | | | | | | |
| 0–5 years | 100 | 39 % | 46 | 37 % | 54 | 40 % | 0.92 |
| 6–10 years | 51 | 20 % | 25 | 20 % | 26 | 19 % | |
| 11–20 years | 77 | 30 % | 39 | 31 % | 38 | 28 % | |
| 21–30 years | 31 | 12 % | 14 | 11 % | 17 | 13 % | |
| Supervision of surgical trainees | | | | | | | |
| yes | 221 | 85 % | 110 | 89 % | 111 | 82 % | 0.14 |
| no | 38 | 15 % | 14 | 11 % | 24 | 18 % | |
| Specialty | | | | | | | |
| General orthopaedics | 12 | 4.6 % | 6 | 4.8 % | 6 | 4.4 % | 0.61 |
| Orthopaedic traumatology | 83 | 32 % | 38 | 31 % | 45 | 33 % | |
| Shoulder and elbow | 34 | 13 % | 20 | 16 % | 14 | 10 % | |
| Hand and wrist | 116 | 45 % | 52 | 42 % | 64 | 47 % | |
| Other | 14 | 5.4 % | 8 | 6.5 % | 6 | 4.4 % | |

evaluate the best predictors at the $p \leq 0.05$ level. Comorbidities were quantified with the continuous Charlson Comorbidity Index Score [12,13] for statistical analysis purposes.

## Results

Surgeons that received measurements only recommended operative treatment slightly, but significantly more often (55 vs. 52 %, $p$=0.01). In addition, they had slightly but significantly less agreement than surgeons that viewed radiographs (fair $\kappa$= 0.39 vs. moderate $\kappa$ =0.45, $p$ <0.001). Surgeons from the United States and Canada, surgeons not supervising surgical trainees, and hand and wrist surgeons were more likely to agree on treatment choice. (Table 2)

Surgeon factors significantly associated with a greater likelihood of recommending operative treatment in bivariate analysis were receiving measurements without viewing radiographs, sex of the surgeon, area and years of practice, and the specialty. (Table 3) The best multivariable model of surgeon factors associated with recommendation for surgery included radiographic measurements, surgeons in Europe and countries other than North America, younger surgeons (less than 21 years of practice) and hand and wrist surgeons, but these factors explained only 1.4 % of the variation in treatment recommendations (R-square=0.014, AUC=0.56). (Table 4)

Patient factors associated with a recommendation for surgery in bivariate analysis included age, sex, side, comorbidities, known osteoporosis, relevant medication, and known alcohol or drug abuse. (Table 5) Radiographic information (e.g. AO type, fracture of the ulnar

**Table 2** Differences in interobserver agreement among surgeons

| Multirater Agreement | Total | | | Measurements and clinical information | | | Radiographs and clinical information | | | Z-value | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agreement | Kappa | SE | Agreement | Kappa | SE | Agreement | Kappa | SE | | |
| Overall | fair | 0.37 | 0.0018 | fair | 0.39 | 0.0024 | moderate | 0.45 | 0.0035 | 13 | <0.001 |
| Area of practice | | | | | | | | | | | |
| United States and Canada | moderate | 0.44 | 0.0024 | moderate | 0.47 | 0.0039 | moderate | 0.51 | 0.0046 | 6.7 | <0.001 |
| Europe and United Kingdom | fair | 0.32 | 0.0037 | fair | 0.35 | 0.0074 | fair | 0.38 | 0.0088 | 3.2 | 0.0016 |
| Other | fair | 0.28 | 0.013 | fair | 0.22 | 0.025 | fair | 0.37 | 0.017 | 4.9 | <0.001 |
| Years of practice | | | | | | | | | | | |
| 0–5 years | fair | 0.37 | 0.0042 | fair | 0.38 | 0.0059 | moderate | 0.46 | 0.0087 | 7.3 | <0.001 |
| 6–10 years | fair | 0.37 | 0.0052 | moderate | 0.43 | 0.011 | fair | 0.37 | 0.010 | 4.2 | <0.001 |
| 11–20 years | fair | 0.37 | 0.0052 | fair | 0.38 | 0.0073 | moderate | 0.44 | 0.011 | 4.1 | <0.001 |
| 21–30 years | fair | 0.39 | 0.0086 | fair | 0.30 | 0.019 | moderate | 0.54 | 0.017 | 10 | <0.001 |
| Supervision of surgical trainees | | | | | | | | | | | |
| yes | fair | 0.37 | 0.0021 | fair | 0.38 | 0.0027 | moderate | 0.44 | 0.0042 | 13 | <0.001 |
| no | moderate | 0.41 | 0.0074 | moderate | 0.43 | 0.019 | moderate | 0.44 | 0.012 | 0.7 | 0.46 |
| Specialty | | | | | | | | | | | |
| Trauma & Orthopaedic | fair | 0.35 | 0.0028 | fair | 0.31 | 0.0060 | moderate | 0.46 | 0.0054 | 18 | <0.001 |
| Shoulder and elbow | fair | 0.36 | 0.0077 | fair | 0.36 | 0.013 | moderate | 0.44 | 0.020 | 3.2 | 0.0014 |
| Hand and wrist | moderate | 0.40 | 0.0051 | moderate | 0.46 | 0.0071 | moderate | 0.45 | 0.0085 | 1.1 | 0.27 |

*SE* Standard error

styloid, dorsal comminution, and dorsal tilt) also had a significant effect on treatment recommendations. The best multivariable model of patient factors associated with a recommendation for surgery included younger age, female patients, left wrist, fewer comorbidities, diagnosed osteoporosis, no known substance abuse with an intra-articular fracture, ulnar styloid process fracture, dorsal comminution, and a more pronounced dorsal tilt and accounted for 38 % of the variation in treatment recommendations (R-square=0.38, AUC=0.82). (Table 6)

## Discussion

Decision making in distal radius fracture is complex and the treatment is strongly influenced by fracture pattern and deformity visualized on radiographs. In daily practice, we often see doctors estimating angles and displacements visually from radiographic films. Visual estimation however is less reliable and accurate than computer software measurement (PACS) [14,15]. The reliability of "precise" measurements taken from radiographs is however also low, reliable measurement of published guidelines on acceptable radiological reduction must be questioned [6]. Computerized digital analysis of radiographs might improve precision and speed [16,17]. While visual estimation and radiographic measurements have limited reliability guidelines with precise threshold values are described [14,18]. We investigated if agreement on treatment recommendations would improve if surgeons were provided with precise radiographic measurements rather than radiographs. Numbers may be processed differently than visual estimations of angles and this difference might affect decision-making. We are not aware of similar studies.

There are several limitations to this study. First, whilst our study is artificial, it helps to understand the sources of variability between surgeons and might lead to more consistent and higher quality care. This study is not meant to have an impact on patient care in isolation. Second, surgeons participating in the Science of Variation Group may not be representative of the average surgeon. This is less important given the randomization. Third, the posteroanterior and lateral views of the wrist were sometimes imperfect in the emergency room due to pain and difficulty with positioning. This replicates the normal situation in emergency departments, but might affect the measurements [6,19,20]. Fourth, radiographic measurements as well as distal radius fracture classifications must be interpreted with caution since their reliability can be low [4,20]. Finally, there may be a spectrum bias due to the use of only 30 consecutive patients (e.g. this may explain the higher

**Table 3** Surgeon factors associated with greater likelihood of recommending operative treatment, bivariate analysis

| Surgeon factor | Rate# | p-value |
|---|---|---|
| Randomization* | | |
| Radiographs and clinical information | 52 % | 0.01 |
| Measurements and clinical information | 55 % | |
| Sex* | | |
| Male | 53 % | 0.021 |
| Female | 58 % | |
| Area of practice* | | |
| United States and Canada | 52 % | <0.001 |
| Europe and United Kingdom | 52 % | |
| Other | 59 % | |
| Years of practice* | | |
| 0–5 years | 55 % | 0.003 |
| 6–10 years | 51 % | |
| 11–20 years | 55 % | |
| 21–30 years | 49 % | |
| Supervision of surgical trainees | | |
| yes | 53 % | 0.47 |
| no | 52 % | |
| Specialty* | | |
| Trauma & Orthopaedic | 51 % | <0.001 |
| Shoulder and elbow | 51 % | |
| Hand and wrist | 57 % | |

# Surgeons who reported offering operative treatment

* entered in multivariable logistic regression

**Table 4** Surgeon factors associated with greater likelihood of recommending operative treatment, multivariable analysis

| Surgeon factor | OR | 95%CI | | p-value |
|---|---|---|---|---|
| | | Lower | Upper | |
| Randomization | | | | |
| Measurements and clinical information | 1.10 | 1.01 | 1.21 | 0.04 |
| Area of practice | | | | |
| Europe and United Kingdom vs. United States and Canada | 1.22 | 1.08 | 1.37 | 0.001 |
| Other vs. United States and Canada | 1.47 | 1.27 | 1.69 | <0.001 |
| Years of practice | | | | |
| 0–5 years vs. 21–30 years | 1.32 | 1.14 | 1.54 | <0.001 |
| 11–20 years vs. 21–30 years | 1.24 | 1.06 | 1.45 | 0.007 |
| Specialty | | | | |
| Hand and wrist vs. Trauma & Orthopaedic | 1.42 | 1.27 | 1.59 | <0.001 |

CI, Confidence interval; OR, Odds ratio

Best model: r2=0.014; AUC 0.56 (0.55–0.57)

**Table 5** Patient factors associated with greater likelihood of recommending operative treatment, bivariate analysis

| Patient factor | Rate# | p-value |
|---|---|---|
| Age* | | |
| Continuous | | <0.001 |
| Sex* | | |
| Male | 50 % | <0.001 |
| Female | 60 % | |
| Side* | | |
| Left | 55 % | <0.001 |
| Right | 51 % | |
| Comorbidities* | | |
| Continuous∇ | | <0.001 |
| Osteoporosis* | | |
| No | 51 % | <0.001 |
| Known osteoporosis | 77 % | |
| Medications* | | |
| No | 53 % | <0.001 |
| Relevant medication | 76 % | |
| Substance abuse* | | |
| No | 55 % | <0.001 |
| Known abuse | 39 % | |
| AO-Type* | | |
| Extra-articular (AO-Type A) | 50 % | <0.001 |
| Intra-articular (AO-Type B or C) | 56 % | |
| Ulnar styloid process fracture* | | |
| No | 44 % | <0.001 |
| Yes | 72 % | |
| Dorsal comminution* | | |
| No | 39 % | <0.001 |
| Yes | 59 % | |
| Dorsal tilt* | | |
| continuous | | <0.001 |

# Surgeons who reported offering operative treatment

* entered in multivariable logistic regression

∇measured with Charlson Comorbidity Index Score

operative recommendation rate for left sided wrist fractures).

Surgeons that received measurements only were less likely to agree with each other and more likely to recommend surgery than surgeons that viewed radiographs. This suggests that a subset of surgeons are more strongly influenced by radiographic parameters than others and that such surgeons might underestimate the amount of deformity when they look at or measure radiographs as shown by Robertson et al. [14]. Given the unreliability of measurements and classifications, it is also possible that our measurements or interpretations of the radiographs were worse than the measurements of the average surgeon. Another possibility is that the radiographic appearance of the fracture might

**Table 6** Patient factors associated with greater likelihood of recommending operative treatment, multivariable analysis

| Patient factor | OR | 95%CI | | p-value |
|---|---|---|---|---|
| | | Lower | Upper | |
| Age | | | | |
| continuous | 0.991 | 0.987 | 0.995 | <0.001 |
| Sex | | | | |
| Female | 1.6 | 1.4 | 1.9 | <0.001 |
| Side | | | | |
| Left | 1.4 | 1.2 | 1.6 | <0.001 |
| Comorbidities | | | | |
| continuous | 0.68 | 0.63 | 0.73 | <0.001 |
| Osteoporosis | | | | |
| Known osteoporosis | 2.1 | 1.7 | 2.6 | <0.001 |
| Substance abuse | | | | |
| Known abuse | 0.39 | 0.33 | 0.47 | <0.001 |
| AO-Type | | | | |
| Intra-articular (AO-Type B or C) | 3.1 | 2.7 | 3.6 | <0.001 |
| Ulnar styloid process fracture | | | | |
| Yes | 1.2 | 1.0 | 1.4 | 0.04 |
| Dorsal comminution | | | | |
| Yes | 1.3 | 1.1 | 1.5 | 0.004 |
| Dorsal tilt | | | | |
| continuous | 1.081 | 1.075 | 1.086 | <0.001 |

CI, Confidence interval; OR, Odds ratio

Best model: r2=0.38; AUC 0.82 (0.81–0.83)

provide some unmeasured or unmeasurable findings that decrease enthusiasm for surgery and increase reliability of decision-making [21]. Last, we expected to have a higher agreement among surgeons receiving measurements only by eliminating an interpretation bias of radiographs. However, the opposite finding may suggest that surgeons rather disagree about the recommendations for surgery than about the interpretation of radiographs.

Younger surgeons and hand and wrist surgeons were more likely to recommend operative treatment. This is consistent with other studies [22–24]. On the other hand, the differences in the overall operative treatment recommendation rates were small (between 49 and 59 %), of questionable clinical relevance, and surgeon factors explained less than 2 % of the variation.

Radiographic parameters, whether provided via radiographs or measurements, were the predominant factors accounting for variation in recommendations for surgery, a finding consistent with other studies [1,25,26].

On the basis of this data we conclude that variations in radiographic interpretation of fractures have a measurable influence on variation in treatment recommendation. What is clear from the accumulated studies on surgeon variation is that there are personal beliefs and biases that have an influence beyond objective measurements and measurement imprecision. Efforts to reduce variation in surgeon recommendations will need to address the variations in training, experience, and values that are at the heart of these biases.

**Ethical Standards** All named authors hereby declare that they have no direct conflicts of interest to disclose related to this study. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. The study was completed under an IRB approved protocol.

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## Science of variation group

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